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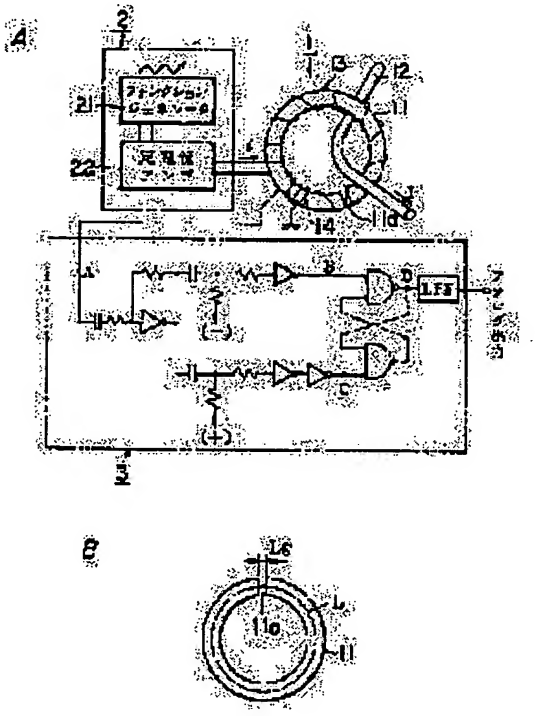
(54) DC CURRENT SENSOR

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a high sensitivity DC current sensor having relatively simple structure and exhibiting a detection capability excellent in the linearity over a wide current variation range from a micro current level to a current level of 100A or above.

SOLUTION: The DC current sensor is constituted by applying an exciting coil 13 and a detection coil 14 troidally around a C-shaped core of soft magnetic material provided with an air gap of specified dimension at one point in the circumferential direction thereof. When the exciting coil 13 is fed with a triangular exciting current generating a field exceeding the coercive force of the core 11, flux in the core 11 is inverted and the inversion timing is detected based on a pulse voltage induced in the detection coil 14. Subsequently, the absolute value and the direction of a DC current flowing through a lead wire to be detected are determined by comparing the pulse intervals.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] Detection of the analog current signal from the various sensors by which this invention was installed in the large-sized facility of the current measurement in the maintenance control of a switchboard control circuit signal etc., an iron mill, etc., The direct-current sensor used in wide range fields, such as current measurement for controlling a small direct current machine machine, is started. Structure is comparatively easy and is related with the direct-current sensor of the high sensitivity which has the ability to detect which was excellent in linearity also to the wide range change (for example, about 3A-300A) from a minute current to a comparatively big current.
[0002]
[Description of the Prior Art] In order for the device which used the direct current by many technical fields to increase and to operate these devices safely and smoothly recently, measurement of a direct current is indispensable and the need for the direct-current sensor of high sensitivity has increased. As these direct-current sensors, the hall device method, the magamp method, the magnetic multivibrator method (JP,47-1644,A, JP,53-31176,A, JP,59-46859,A), etc. are learned.
[0003] It is difficult to measure the current below 20A to high degree of accuracy (about **2%) comparatively, when a hall device well-known from the ability to detect being inevitably determined with the property of a hall device although a hall device method has comparatively simple structure and handling is also easy now is used, and was restricted to the use in an application with a usually big (for example, 20A is exceeded) detection current.
[0004] It is necessary to carry out DC magnetic deviation so that the core of a soft magnetic material may be mostly saturated with the direct current which flows to a detected lead wire while structure is complicated, although measurement of a comparatively small current is [on the other hand / a hall device method] possible for a magamp method and MAG multivibrator method even near saturation magnetic flux density (Bs), and according to a detection current, several 100 or more ******s of detected lead wire will be wound around this core from several 10 turns, and an application is limited sharply.
[0005] The direct-current sensor of a configuration of that current change of 0.2A-20A can be caught with a comparatively easy configuration from the ability of a hall device method, a magamp method, a magnetic multivibrator method, etc. which are learned from the former not to respond to the current change from an about [0.2A-20A] minute current to a comparatively big current was called for.
[0006] Then, an applicant for this patent sets an exiting coil and a sensing coil to the shape of toroidal one in the easiest configuration that carried out winding arrangement at the core which consists of an annular soft magnetic material previously. When the exciting current of the shape of a triangular wave which makes an exiting coil generate the magnetic field exceeding the coercive force of a core is passed, Paying attention to the sense of magnetic flux incore being reversed, the timing of this reversal is detected on the electrical potential difference of the shape of a pulse generated in a sensing coil. By carrying out relative measurement of these pulse separations corresponding to change of the absolute value of the direct current which flows to a detected lead wire by which penetration arrangement is carried out to incore The knowledge of becoming possible to detect the absolute value of the direct

current which flows to this detected lead wire was carried out, and the direct-current sensor which consists of a configuration of having the above-mentioned annular core was proposed (JP,7-128373,A).
[0007]
[Problem(s) to be Solved by the Invention] In order that the above-mentioned direct-current sensor may generate the magnetic field which exceeds the coercive force of this core to annular incore [which has the exiting coil and sensing coil which carried out winding arrangement in the shape of toroidal one], it passes a triangular wave-like exciting current to said exiting coil, and detects it on the electrical potential difference of the shape of a pulse which generates the timing which the sense of magnetic flux incore reverses in said sensing coil.
[0008] However, if it is superimposed on the magnetic field incore generated according to a triangular wave-like exciting current, and the magnetic field incore generated according to the direct current which flows to a detected lead wire and incore is saturated by these magnetic fields There was a problem from which one side of the pulse separations t1 and t2 which the magnetic field change by incore is lost, and an output pulse is not obtained in the time amount region saturated as a result, and are generated in a crest [of a triangular wave] or trough side becomes very small, and measurement of high sensitivity becomes difficult. When the direct current which flows to a detected lead wire in the configuration which has said annular core especially exceeded 20A, one pulse gaps t1 or t2 were not able to be substantially set to 0, and the target amperometry was not able to be realized.
[0009] Structure is easy like the conventional annular core mold configuration, and this invention aims at offer of the direct-current sensor of the high sensitivity which has the ability to detect which was excellent in linearity also to the wide range change from a comparatively minute current to the high current more than 100A.
[0010]
[Means for Solving the Problem] The result variously examined for the purpose of the configuration of the direct-current sensor which can demonstrate the ability to detect artificers excelled [ability to detect] in linearity also to the wide range change from a comparatively minute current to the high current more than 100A, If the opening of a predetermined dimension is formed in one place of the hoop direction of the conventional annular core, the hysteresis curve of this core inclines toward the one where the absolute value of a magnetic field is bigger, maintaining similarly the direct-current sensor which consists of a configuration of having the conventional annular core, and a fundamental function. The saturation point of a core will move to the one where the absolute value of a magnetic field is bigger as a result. It could realize expanding the range until a core is saturated substantially, the ability to detect excellent in linearity was expanded, the knowledge of the ability to respond to the wide range change to an about [300A] high current was carried out, and this invention was completed.
[0011] The core to which this invention becomes inside from the annular soft magnetic material which carries out penetration arrangement of the detected lead wire with which the direct current which carries out non-contact detection flows, It has the exiting coil and sensing coil which carried out winding arrangement to this core at the shape of toroidal one. And it consists of a configuration which forms an opening in at least one place of the hoop direction of said core. The exciting current of the shape of a triangular wave which makes said exiting coil generate the magnetic field which exceeds the coercive force of this core to incore A sink, It is the direct-current sensor characterized by detecting the absolute value of the direct current which flows to a detected lead wire by detecting on the electrical potential difference of the shape of a pulse which generates the timing which the sense of magnetic flux incore reverses in said sensing coil, and carrying out relative measurement of the spacing of this pulse.
[0012]
[Embodiment of the Invention] An operation is explained to the configuration list of the direct-current sensor of this invention at a detail based on drawing 1 - drawing 3 . First, drawing 1 is the outline explanatory view showing one example of the direct-current sensor of this invention, and 1 shows the body section of a direct-current sensor. The core 11 which consists of a soft magnetic material which is the description of this invention The configuration which cut one place to the hoop direction of an annular core so that it might be set to opening 11a of a predetermined dimension, For example, after

piercing the soft magnetic material which consists of a well-known permalloy etc. to abbreviation ring-like C character type and performing predetermined heat treatment, it consists of a configuration which carried out the laminating of two or more sheets, and has been arranged in an insulating resin case, and penetration arrangement of the detected lead wire 12 with which the direct current which carries out non-contact detection flows inside has been carried out.

[0013] To this C character type core 11, winding arrangement of the exiting coil 13 is carried out at the shape of toroidal one. Moreover, winding arrangement of the sensing coil 14 is carried out like the exiting coil 13 at the shape of toroidal one at the above-mentioned core 11. Moreover, in drawing 1 , 2 is a power supply section linked to an exiting coil 13, consists of a function generator and constant current amplifier, and passes the exciting current of a predetermined triangular wave mentioned later. Moreover, 3 is the electrical circuit section linked to a sensing coil 14, and obtains predetermined analog output based on the pulse voltage detected with the sensing coil 14 mentioned later. In addition, exiting coil 13 the very thing can be made to share the function of a sensing coil 14 by adding the circuit which takes out only a pulse component electrically also to an exiting coil 13 from the electrical potential difference of the shape of an above pulse occurring.

[0014] Here, the magnetic properties of C character type core 11 are explained based on drawing 3 . In the case of the conventional annular core in which an opening does not exist, it usually has a hysteresis curve as shown in I in drawing. When opening 11a is prepared in the hoop direction of a core, as shown in drawing China and Russia, saturation magnetic flux density (Bs) and coercive force (Hc) will incline toward the one where the absolute value of a magnetic field (H) is bigger still more greatly, without changing substantially. That is, the saturation point will move to the one where the absolute value of a magnetic field (H) is bigger (C->D in drawing, -C->-D, and migration), and the range of magnetic field strength until a core is saturated will be expanded. Therefore, it becomes possible to prevent contraction of the remarkable output pulse gap which is generated in the case of the conventional annular core, and a highly precise measuring range which was substantially excellent in linearity will be expanded.

[0015] In addition, although change of the flux density (B) to change of the same magnetic field becomes small and an output value becomes small a little since magnetic resistance becomes large as compared with the case where there is no opening in the case of the core 11 of this invention, it is possible to maintain the same precision as the case where there is no opening by the electric magnification in a measuring circuit. Moreover, since there is no change in saturation magnetic flux density (Bs) and coercive force (Hc) so that clearly also from drawing 3 , as compared with a residual magnetic flux density (B1) in case there is no opening, it becomes a small value, the effect of **** given to output characteristics decreases greatly, and the residual magnetic flux density in the case of the core 11 of this invention (B-2) enables highly precise measurement which was further excellent in linearity.

[0016] In the configuration which has arranged the core 11 which has the hysteresis curve explained above, the exciting current i of the shape of a triangular wave which makes an exiting coil 13 generate the magnetic field exceeding the coercive force of this core 11 in this core 11 is passed. That is, if peak value of a current is set to ip and coercive force of a core 11 is set to Hc, the peak value ip of a triangular wave-like exciting current will be set up so that it may become Hc<<Nip/l. In addition, N is the number of turns of an exiting coil 13, and l is the magnetic-path length of a core 11 here. When Current I is not flowing to the detected lead wire 12 (I= 0), and an exciting current i increases and it becomes nickel/l=Hc, and when an exciting current i decreases and it is set to nickel/l=-Hc, the sense of the magnetic flux in a core 11 is quickly reversed, respectively, and the pulse voltage of the reverse sense occurs in a sensing coil 14 at the time of this reversal. Here, if the coercive force (Hc) of a core 11 is symmetrical with positive/negative, it will not be based on the magnitude of coercive force (Hc), but the pulse separations t1 and t2 generated in a crest [of a triangular wave] and trough side will become equal.

[0017] Moreover, when Current I is flowing to the detected lead wire 12 (I=I0), it sets. According to the current I which flows to the detected lead wire 12 in addition to the magnetic field generated by the change in an exciting current i which was explained above in the core 11 Since a magnetic field (I0/l) is

formed beforehand, it is superimposed on these magnetic fields and an exciting current i increases, and the magnetic field H in the excitation core 11 is H. = nickel/l - I0/l = When set to +Hc, Moreover, an exciting current i decreases and the magnetic field H in the excitation core 11 is H. = nickel/l - I0/l = - When set to Hc, the sense of the magnetic flux in a core 11 is quickly reversed, respectively, and the pulse voltage of the reverse sense will occur in a sensing coil 14 at the time of this reversal.

[0018] Since in the case of the core 11 of this invention the range of magnetic field strength until a core is saturated is wide even if the current I which flows to the detected lead wire 12 is large, as explained previously, generating of each pulse voltage is performed good and comparatively large pulse separation are obtained. In addition, in this case, even if the coercive force (Hc) of a core 11 is symmetrical with positive/negative, a difference will arise in the pulse separations t1 and t2 generated in a crest [of a triangular wave], and trough side. However, uniformly [change per time amount of an exciting current i], when the absolute value of the inclination at the time of an increment and reduction is equal (di (increment)/dt=-di(reduction)/dt = fixed), the current I which flows to the detected lead wire 12 is proportional to {(t2-t1) / (t2+t1)}.

[0019] Therefore, it becomes possible to detect the absolute value and sense of the current I which is flowing to the detected lead wire 12 by measuring pulse separations t1 and t2 electrically, respectively by measuring beforehand correlation with the current I which is flowing to the difference and the detected lead wire 12 of these pulse separations t1 and t2. For example, in the configuration shown in drawing 1 , if the exciting current i of the shape of a predetermined triangular wave is passed to an exiting coil 13 from the power supply section 2 which consists of a function generator and constant current amplifier while Current I is flowing to the detected lead wire 12, the electrical potential difference of the shape of a pulse corresponding to the absolute value of Current I is detected by the sensing coil 14, and, finally predetermined analog output can be obtained through an electrical circuit 3. In addition, the outline of the electrical signal in each location A-D shown in the electrical circuit 3 of drawing 1 is shown in drawing 2 .

[0020] In this invention the dimension Lg of opening 11a of C character type core 11 Since it becomes impossible to maintain the precision of minute current **** when the successive range of the above-mentioned saturation point is small when the value is too small, the expansion effectiveness of measuring range is small and Lg is too large conversely, a ratio with the overall length L of a core hoop direction including the die length Lg and this opening of a hoop direction of the opening formed in a core as shown in drawing 1 B -- it is desirable to make Lg/L into the range of 0.001-0.05. Although an opening is one case, the example to illustrate can prepare two or more places if needed, and is good to make it the sum total dimension of two or more openings serve as the above-mentioned range in this case. In addition, in the conventional direct-current sensor mentioned above, as magnetic reluctance does not increase as much as possible in a joint, this does not have an opening substantially from adopting the configuration of draw-down or a fitting type, and although the configuration of an assembled die is proposed, it does not do the operation effectiveness of this invention so at all so that clearly [an example].

[0021] Although the direct-current sensor of this invention shown above makes indispensable the configuration which established the opening in the hoop direction as a core in various annular soft magnetic materials, such as the shape of ellipse annular besides the shape of a circular ring, and a rectangle frame, it is desirable to select the quality of the material of this soft magnetic material according to the detection sensitivity required of the magnitude of the current which flows to a detected lead wire, i.e., a sensor. usually -- although a permalloy is desirable when workability etc. is taken into consideration with magnetic properties -- in addition, a silicon steel plate, amorphous one, and electromagnetism -- use of well-known soft magnetic materials, such as soft iron and a soft ferrite, is possible, and you may use combining these. Moreover, although these soft magnetic materials may be constituted from a veneer, it is also possible to carry out the laminating of the soft magnetic material of two or more sheets like the example explained previously, and to adopt a unification configuration. Furthermore, it is desirable to cover the direct-current sensor of this invention with the shielding case which consists of a permalloy, a nondirectional silicon steel plate, etc. if needed, and to prevent mixing

of an induction noise.
[0022]
[Example] After piercing the permalloy C (78%nickel-5%Mo-4%Cu-balFe) which consists of sheet metal with a thickness of 0.5mm with an outer diameter [of 43mm], and a bore of 32mm in the shape of a ring and heat-treating 1100 degree-Cx3hr in a hydrogen gas ambient atmosphere further, heat treatment which performs multistage cooling processing for for 600 degrees C-400 degrees C by 100 degrees C/hr was made to complete, and the core material which constitutes the conventional direct-current sensor was created. Furthermore, using the same core material, the opening of one place and 1mm die length was established in the circumferencial direction, and the core material which constitutes the direct-current sensor of this invention was created. In the case which consists of insulating resin, respectively, the laminating of this core material and the ten sheets was carried out, they have been arranged, and it considered as C character type core at the annular list. In addition, Lg/L of the core material of this invention was 0.008.
[0023] 950 ******s of polyurethane covering copper wire with an outer diameter of 0.45mm were wound around the core in the shape of toroidal one, and it considered as the exiting coil. Moreover, 950 ******s of polyurethane covering copper wire with an outer diameter of 0.45mm were wound in the shape of toroidal ones, and it considered as the sensing coil. These exiting coils and sensing coils were connected to a power supply section and the analog electrical circuit section, and the direct-current sensor of this invention was completed. After carrying out penetration arrangement of the detected lead wire which becomes incore from vinyl covering with an outer diameter of 8mm, while passing the exponential current of 27Hz and ip=**0.5A to said exiting coil, the final output characteristics when changing the direct current (detected current) passed to a detected lead wire are shown in drawing 4 . From this result, the direct-current sensor of this invention has checked that it was measurable in the range of 3A-100A in **2% of precision.
[0024] moreover, it is also possible by using a digital electrical circuit to expand a minute current region to about 100mA -- the thing check was carried out. Furthermore, it checked that **5% of precision was securable in the range of 3A-300A with selection of the opening dimension of a core, the property of an exciting current, an electrical circuit, etc. On the other hand, similarly measurement of the conventional direct-current sensor using a dimension and the quality of the material more than 20A was not completed. Therefore, it is clear that the direct-current sensor's of this invention it can be adopted as various applications and this effect of the invention can be especially realized effectively in control of the direct current machine machine of a high current or maintenance control.
[0025]
[Effect of the Invention] The direct-current sensor of this invention to the core which becomes a fundamental configuration from the soft magnetic material of the shape of a C character which prepared the opening of a predetermined proportion The easy configuration which carried out winding arrangement of an exiting coil and the sensing coil at the shape of toroidal one is adopted. The exciting current of the shape of a triangular wave which makes an exiting coil generate the magnetic field exceeding the coercive force of a core A sink, By detecting on the electrical potential difference of the shape of a pulse which generates the timing which the sense of magnetic flux incore [at that time] reverses in a sensing coil, and carrying out relative measurement of these pulse separations From it being the configuration of detecting the absolute value and sense of the direct current which flows to a detected lead wire An electrical circuit is not so complicated, either and can be adopted as control of various direct current machine machines or a sensor for maintenance control from having the wide range current change from a moreover comparatively minute current to a big current, for example, the ability to detect which was excellent in linearity to about 3A-300A.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] A is the outline explanatory view showing one example of the direct-current sensor of this invention, and B is the explanatory view showing the core of a sensor.
[Drawing 2] A-D is the explanatory view showing the outline of the electrical signal in the part of A-D of the electrical circuit shown in drawing 1 , respectively.
[Drawing 3] It is the graph which shows the hysteresis curve of the core of a direct-current sensor, and when curve (b) does not have an opening in a core, it is the case where an opening has curve (b) in a core.
[Drawing 4] It is the line chart which shows the relation of the direct current and output which flow to a detected lead wire in the direct-current sensor of this invention shown in drawing 1 .
[Description of Notations]
1 Body Section of Direct-Current Sensor
2 Power Supply Section
3 Electrical Circuit Section
11 Core
11a Opening
12 Detected Lead Wire
13 Exiting Coil
14 Sensing Coil
21 Function Generator
22 Constant Current Amplifier

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CLAIMS

[Claim(s)]
[Claim 1] The core which becomes inside from the annular soft magnetic material which carries out penetration arrangement of the detected lead wire with which the direct current which carries out non-contact detection flows, It has the exiting coil and sensing coil which carried out winding arrangement to this core at the shape of toroidal one. And it consists of a configuration which forms an opening in at least one place of the hoop direction of said core. The exciting current of the shape of a chopping sea which makes said exiting coil generate the magnetic field which exceeds the coercive force of this core to incore A sink, The direct-current sensor characterized by detecting the absolute value of the direct current which flows to a detected lead wire by detecting on the electrical potential difference of the shape of a pulse which generates the timing which the sense of magnetic flux incore reverses in said sensing coil, and comparing spacing of this pulse.
[Claim 2] The direct-current sensor whose opening formed in a core in claim 1 is one place of a hoop direction.
[Claim 3] a ratio with the overall length L of a core hoop direction including the die length Lg and this opening of a hoop direction of the opening formed in a core in claim 2 -- the direct-current sensor whose Lg/L is 0.001-0.05.

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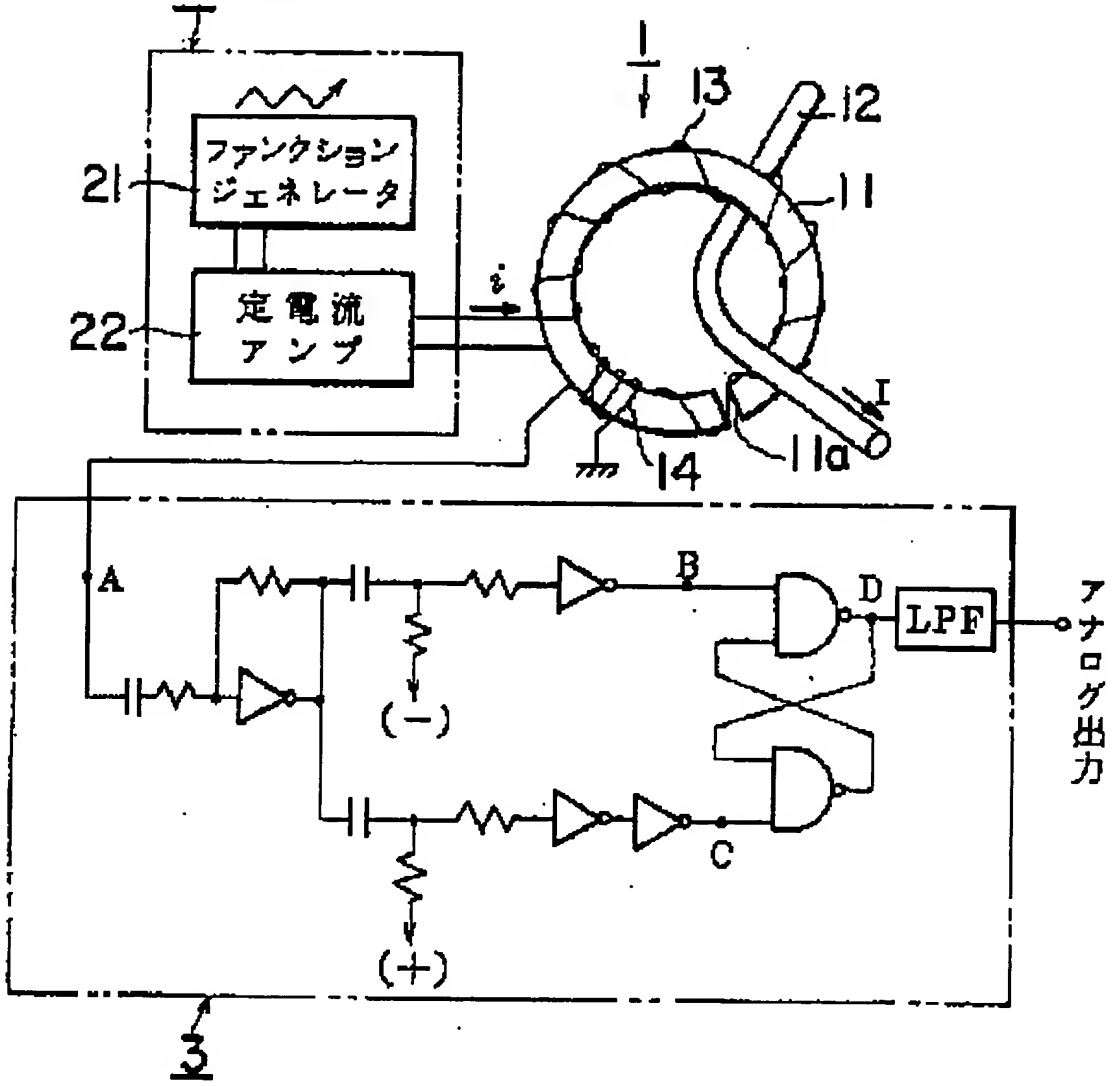
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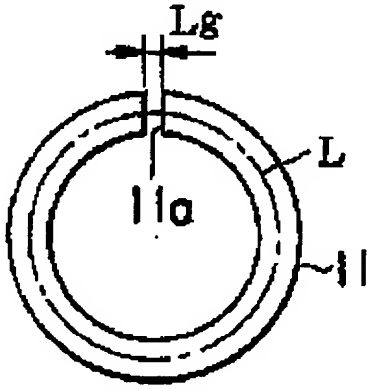
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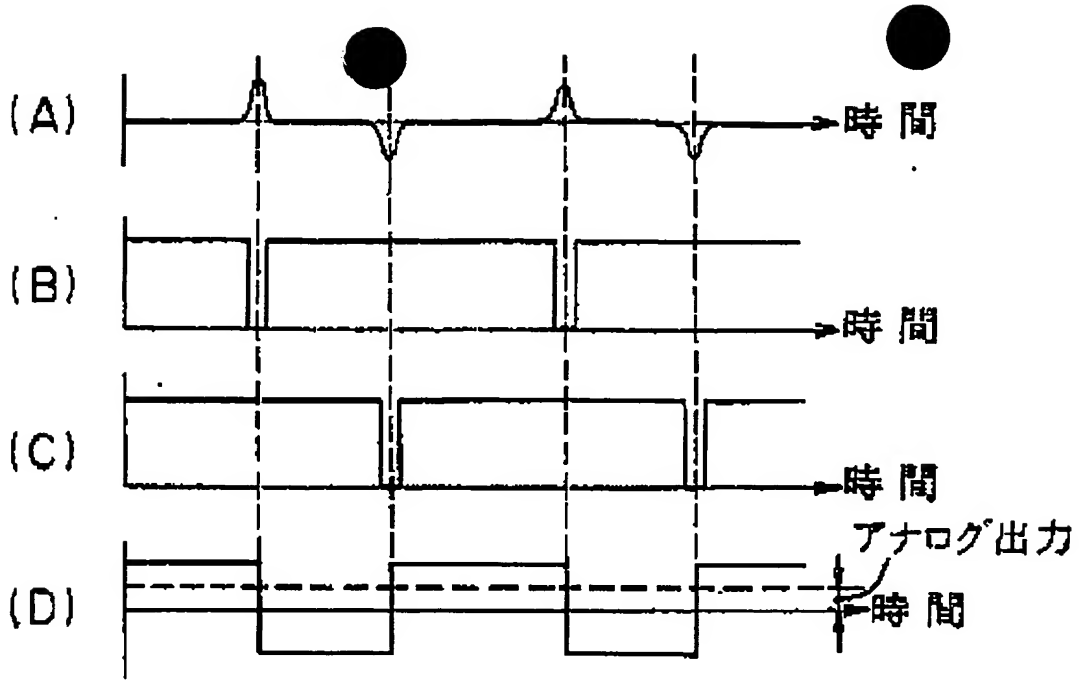
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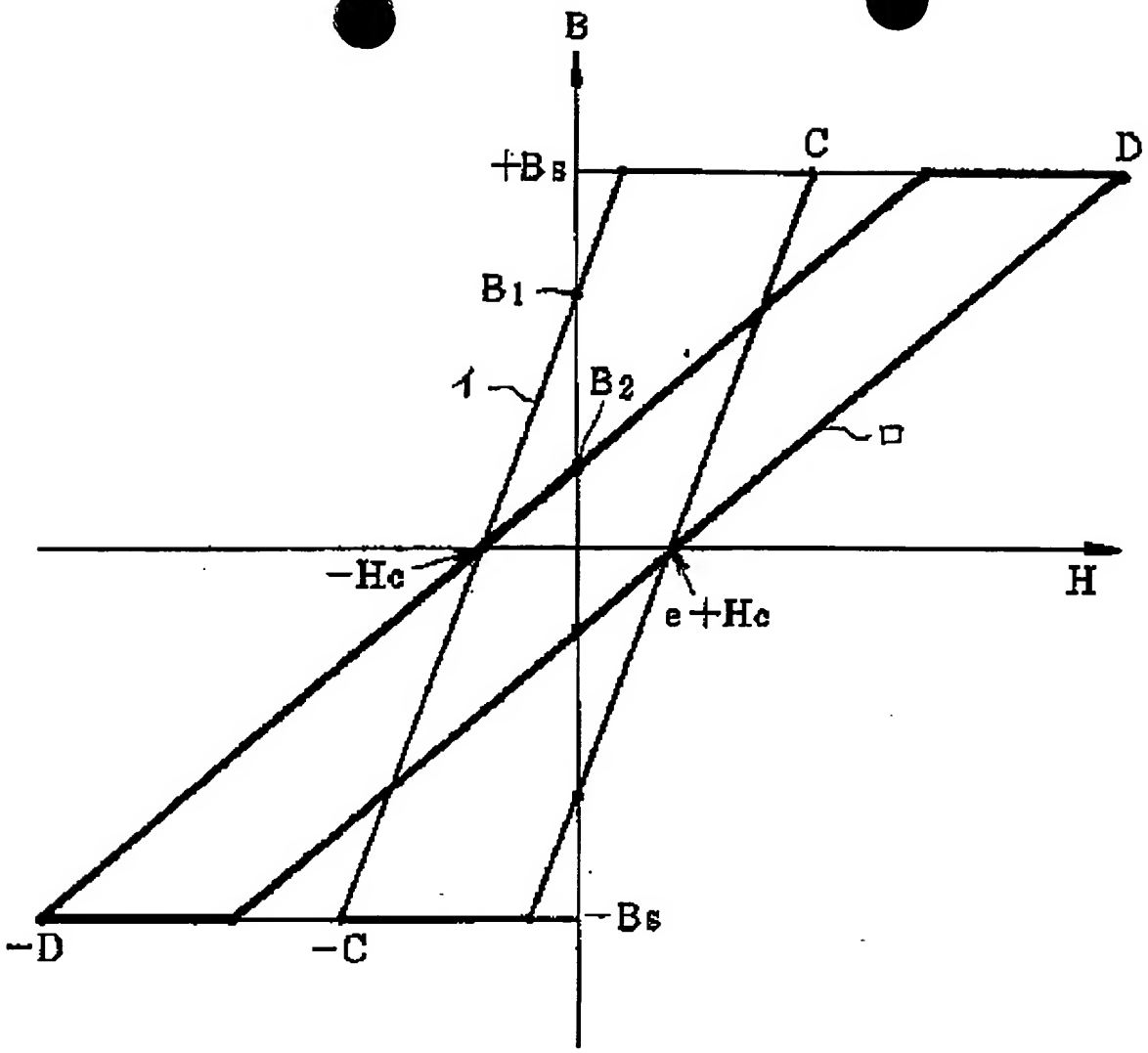
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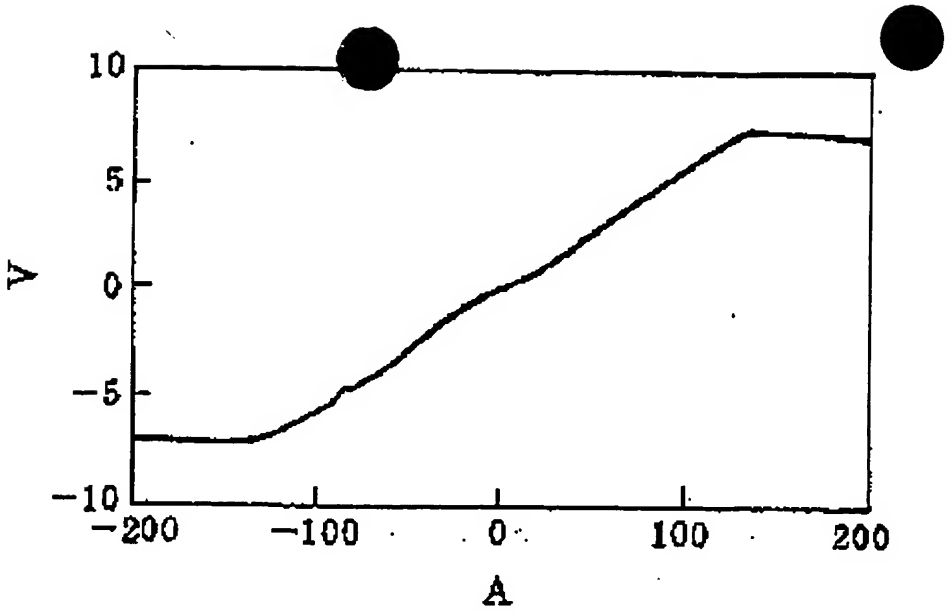
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